P 6: Low Pressure Plasmas I

Zeit: Montag 16:30–18:30 Raum: HS 20

Hauptvortrag P 6.1 Mo 16:30 HS 20

Plasmas in leading-edge semiconductor device fabrication: Importance and analysis — •Sven Zimmermann[1,2], Micha Haase[1], Norbert Lang[3], Henrik Zimmermann[3], Jürgen Röpcke[3], Stefan Schulz[1,2], and Thomas Otto[1,2] — [1]Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]Fraunhofer ENAS Chemnitz, 09126 Chemnitz, Germany — [3]INP Greifswald, 17489, Greifswald, Germany

The further scaling of device dimension in modern semiconductor technologies results in an increasing complexity of plasma processes. Especially patterning processes in the state of the art 22 nm-technology-node become more and more the limiting factor for device performance, reliability and power consumption. Such processes are often multistep recipes with an intermediate change in chemical plasma composition and additional purges. The optimization of such single-step-chains on the empirical way fails due to the unmanageable couple of adjustable parameters and their dependencies. Additional novel materials show often more complex chemical interactions with plasma species.

The talk exemplifies typical challenges for plasma processes in state of the art integration schemes, down to 22 nm, with respect to transistor functionality and performance of the interconnect system. The plasmas were analyzed with several electric and spectroscopic methods and correlations with process results, e.g. material degradations and geometrical aspects, will be illustrated. Finally, drawbacks and furthers requirements of modern plasma diagnostic methods will be given.

P 6.2 Mo 17:00 HS 20

Spectra of the planar Multipole Resonance Probe determined by a Kinetic Model — •Michael Friedrichs and Jens Oberrath — Institute of Product and Process Innovation, Leuphana University Lüneburg, Germany

The planar Multipole Resonance Probe (pMRP) is a measurement device for plasma processes, especially suited for industrial applications. Due to its planar design, the probe can be mounted directly into a chamber wall of a reactor and offers the ability to monitor the plasma during the process. The calculation of plasma parameters requires an appropriate mathematical model to obtain a proportional relation between the resonance and the plasma parameters. A fluid model of the probe-plasma interaction offers the ability to calculate the electron density by measuring the resonance frequency. The information of the electron temperature can be obtained by analyzing another resonance parameter like e.g. the half width of the resonance peak. However, it requires a kinetic description of the resonance phenomenon. In this work a kinetic model, adapted to the pMRP, is analyzed using functional analytic methods. An approximated solution for the admittance of the probe-plasma interaction will be investigated and a study of the influence of the truncation on the resonance spectrum will be shown.

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P 6.3 Mo 17:15 HS 20

Determination of the EEDF by a Langmuir probe AC technique in low pressure ICPs — •Adrian Heiler[1,2], Roland Friedl[1], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

The electron energy distribution function (EEDF) in low pressure plasmas is typically evaluated by using the second derivative $\mathrm{d}^2I/\mathrm{d}V^2$ of a Langmuir probe characteristic (Druyvesteyn formula). Since measured I-V characteristics are inherently noisy, two-time numerical differentiation requires data smoothing techniques which can lead to a loss of information especially in the low energy range of the resulting EEDF. Therefore, an AC probe method was adopted to measure $\mathrm{d}^2I/\mathrm{d}V^2$ directly. This is done by superimposing a sinusoidal AC voltage of 13 kHz and amplitude in the range of 1 V on the probe DC bias and Fourier analysis of the resulting probe current. With this technique the EEDFs are accessible with high accuracy in the low energy range compared to EEDFs determined via numerical differentiation.

The system is applied to several gases (Ar, H_2, D_2, N_2) at an ICP discharge (planar coil, 2 MHz RF frequency, up to 2 kW power). Parameters like the modulation amplitude and number of applied sine oscillations per voltage step of the DC ramp were carefully chosen by systematic parameter variations. The shape of the EEDF for low electron energies, especially important in molecular gases (vibrational excitation processes), is investigated in particular and compared to simulations performed with the Boltzmann solver BOLSIG+.

P 6.4 Mo 17:30 HS 20

The absolute calibration of an energy-selective mass spectrometer with the reference IVDF from a 1D PIC simulation of a symmetrical RF plasma — •Christian Schulze[1], Hanno Kählert[2], Michael Marsand[2], and Jan Benedikt[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Germany — [2]Institute of Theoretical Physics and Astrophysics, Kiel University, Germany

Energy-selective mass spectrometry (ESMS) is a broadly used diagnostic in plasma research due to its versatile applications like residual gas analysis, determination of velocity distributions of ions and neutrals as well as the identification of metastable species. Despite of its frequent use there are very few information about the main artifacts like chromatic abberation, energy dependence of the acceptance angle and mass discrimination that can strongly distort the measurement. Especially the ion lens system with its unknown transmission behavior has a crucial influence on the measured ion signal. Therefore, ESMS provides mainly qualitative information about ion fluxes.

We constructed a symmetric RF CCP setup with the ESMS sampling orifice integrated in the grounded electrode to study IVDFs of the ions that are accelerated in the sheat. The symmetry of the discharge allows for direct comparison to 1D MCC-PIC simulation. The simulation provides angular and velocity resolved absolute ion fluxes. Therefore, the comparison of measured and simulated IVDFs is used to investigate the effects of distortions and calibrate the measured ion signal to the simulated absolute ion flux.

P 6.5 Mo 17:45 HS 20

Operation of INCA with molecular gases — •Christian Lütke Stetzkamp, Philipp Ahr, Tsanko Vaskov Tsankov, and Uwe Czarnetzki — Institute for Plasma and Atomic Physics, Ruhr University Bochum, D-44780 Bochum, Germany

Recently a novel concept for collisionless electron heating and plasma generation at low pressures was theoretically proposed [1]. It is based on periodically structured vortex fields, which produce certain electron resonances in velocity space. The concept was experimentally realized by the inductively coupled array (INCA) discharge and first experimental results in atomic gas plasmas were presented in [2].

Here the discharge is analysed further and the newest experimental results regarding discharge operation in molecular gases are presented and discussed.

[1] U. Czarnetzki and Kh. Tarnev, Phys. Plasmas 21, 123508 (2014)
[2] Philipp Ahr et al, Plasma Sources Sci. Technol. 27, 105010 (2018)

P 6.6 Mo 18:00 HS 20

Phase resolved optical properties of magnetized transient plasma created by a low-pressure dielectric barrier discharge jet — •Roman Bergert and Slobodan Mitic — Justus-Liebig-Universität Gießen

Dielectric barrier discharge (DBD) jet with the influence of an external constant magnetic field (0.3 T) at low pressure (100 Pa) were investigated by tuneable diode laser absorption spectroscopy in perpendicular observation to the magnetic field. With this configuration each π and σ polarized transitions of Argon 1s at 842.47 nm and 1s at 801.48 nm were phase resolved by using unpolarized laser light. The changes within a discharge cycle for each polarization transition and sublevel density were observed to investigate the transient plasma during different regimes. To increase accuracy of our model, we calculate the individual Einstein coefficient for spontaneous decay between magnetic sublevel transitions. This enabled us to observe a significant change in the optical properties of transient plasma with an external magnetic field. This results in a changed average selfabsorption coefficient by almost 0.5 compared to an unsplitted case with same total 1s densities. This shows that the plasma becomes more transparent under the influence of an external magnetic field. The individual transition properties are necessary for a correct description of the plasma emission and absorption with an external magnetic field.

P 6.7 Mo 18:15 HS 20

Measurements of VUV/UV photon fluxes in planar ICP discharges at low pressure — •Caecilia Fröhler[1], Roland Friedl[1], Stefan Briefi[1,2], and Ursel Fantz[1,2] — [1]AG Experimentelle Plasmaphysik, Universität Augsburg, 86135 Augsburg — [2]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching

Photon fluxes in the vacuum ultraviolet spectral region (VUV, wavelength below 200 nm) and in the ultraviolet (UV, wavelength between 200 nm and 400 nm) play a role in plasma treatment processes. They can have beneficial or undesirable effects on the surface material depending on the absolute flux, the photon energy and the application. Therefore, VUV/UV photon fluxes of the gases H_2, N_2, O_2, Ar and mixtures are investigated in a planar ICP discharge (Ø15 cm, height 10 cm; 2 MHz; ≤ 2 kW; 0.3 - 10 Pa) in pressure and power scans with a special focus on the spectral composition. For that purpose, an 1 m McPherson VUV spectrometer is used which can be equipped either with a solar-blind photomultiplier or with a windowless Channel Electron Mulitiplier. Thus, the VUV spectrometer allows measurements in the wavelength range from 50 nm to 300 nm, with an absolute intensity calibration available between 116 nm and 300 nm. Additionally, the results are compared with measurements using a VUV diode system which is under development. In contrast to the VUV spectromter, the diode system is small, portable and its absolute intensity calibration does not depend on the plasma setup of use.